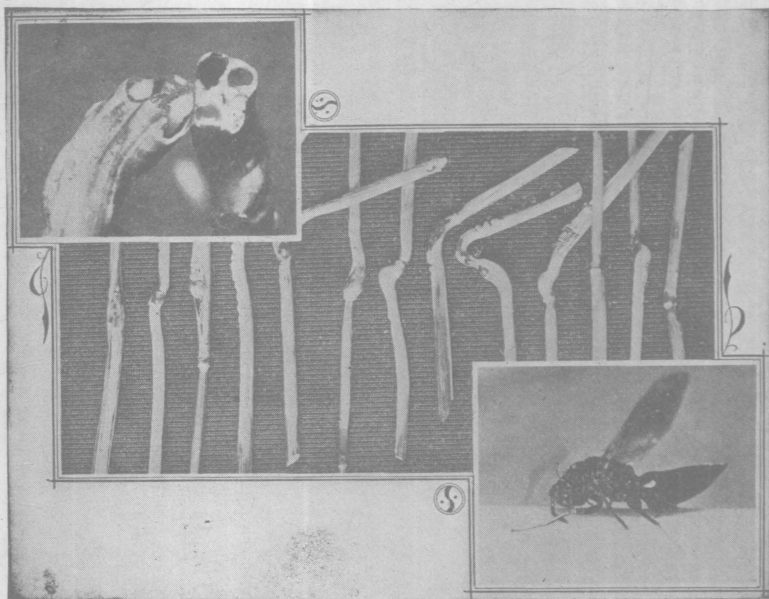


THE WHEAT JOINT WORM

OHIO Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., FEBRUARY, 1911.

BULLETIN 226



The Bulletins of this Station are sent free to all residents of the State who request them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to

EXPERIMENT STATION, Wooster, Ohio

OHIO AGRICULTURAL EXPERIMENT STATION

BOARD OF CONTROL

G. E. JOBE, <i>President</i>	Cedarville
GEORGE E. SCOTT.....	Mt. Pleasant
CHARLES FLUMERFELT.....	Old Fort
MARTIN L. RUETENIK.....	Cleveland
JAMES DEVOL.....	Marietta

WILLIAM H. KRAMER, *Secretary-Treasurer*

STATION STAFF

CHARLES E. THORNE, M. S. A., *Director*

ADMINISTRATION

THE DIRECTOR, *Chief*
WILLIAM H. KRAMER, *Bursar*
W. K. GREENBANK, *Librarian*
CLARENCE M. BAKER, B. S., *Editor*

AGRONOMY

C. G. WILLIAMS, *Associate Director, Chief*
F. A. WELTON, M. S., *Associate*
J. B. PARK, Ph. D., *Hon. Associate*¹
L. E. THATCHER, Ph. G., *Assistant*
C. A. PATTON, *Assistant*
C. E. DIKE, B. S., *Field Assistant*
WILLIAM HOLMES, *Farm Manager*

ANIMAL HUSBANDRY

B. E. CARMICHAEL, M. S., *Chief*
J. W. HAMMOND, M. S., *Associate*
W. J. BUSS, *Assistant*
W. L. ROBISON, M. S., *Assistant*

BOTANY

A. D. SELBY, B. S., *Chief*
TRUE HOUSER, B. S., *Asst., (Germantown)*
FREDA DETMERS, M. S., *Assistant*
ROY C. THOMAS, M. A., *Assistant*

CHEMISTRY

J. W. AMES, M. S., *Chief*
C. J. SCHOLLENBERGER, *Assistant*
MABEL K. CORBOULD, *Assistant*
RAUB H. SIMON, A. M., *Assistant*

CLIMATOLOGY

W. H. ALEXANDER, *Chief (Columbus)*²
C. A. PATTON, *Observer*

DAIRYING

C. C. HAYDEN, M. S., *Chief*
A. E. PERKINS, M. S., *Assistant*
C. F. MONROE, B. S., *Assistant*

ENTOMOLOGY

H. A. GOSSARD, M. S., *Chief*
HERBERT OSBORN, D. Sc., *Hon. Associate*
J. S. HOUSER, M. S. A., *Associate*
W. V. BALDUF, B. A., *Assistant*

FORESTRY

EDMUND SECREST, B. S., *Chief*
J. J. CRUMLEY, Ph. D., *Assistant*
F. W. DEAN, B. S., *Assistant*

HORTICULTURE

W. J. GREEN, *Vice Director, Chief*
PAUL THAYER, M. S., *Associate*
F. H. BALLOU, *Assistant (Newark)*
J. B. KEIL, *Field Assistant*
I. P. LEWIS, B. S., *Field Assistant*
C. W. ELLENWOOD, *Field Assistant*

NUTRITION

E. B. FORBES, Ph. D., *Chief*
O. H. HUNT, A. M., *Assistant*
J. A. SCHULZ, B. S., *Assistant*
A. R. WINTER, B. S., *Assistant*
R. F. REMLER, B. Chem., *Assistant*

SOILS

THE DIRECTOR, *Chief*
C. G. WILLIAMS, *Associate in soil fertility*
J. W. AMES, M. S., *Asso. in soil chemistry*
F. E. BEAR, Ph. D., *Hon. Associate*¹
A. BONAZZI, B. Agr., *Assistant*
G. W. CONREY, A. M., *Assistant*¹

FARM MANAGEMENT

C. W. MONTGOMERY, *Chief*
E. J. UTZ, *Assistant*

DISTRICT EXPERIMENT FARMS

Northeastern Test-Farm, Strongsville
D. S. KIRBY, *Foreman*
Southwestern Test-Farm, Germantown
HENRY M. WACHTER, *Manager*
Southeastern Test-Farm, Carpenter
S. C. HARTMAN, M. S., *Superintendent*
C. H. WILSON, *Manager*
Northwestern Test-Farm, Findlay
JOHN A. SUTTON, *Manager*
COUNTY EXPERIMENT FARMS
{ Miami Co. Experiment Farm, Troy
{ Madison Co. Experiment Farm, London
{Supt., London
Paulding Co. Experiment Farm, Paulding
H. R. HOYT, *Manager*, Wooster
{ Clermont Co. Experiment Farm, Owensville
{ Hamilton Co. Experiment Farm,
{ Mt. Healthy
{ H. W. ROGERS, *Supt.*, Mt. Healthy
{ Washington Co. Experiment Farm, Fleming
{ Washington Co. Truck Experiment Farm,
{ Marietta
{ S. C. HARTMAN, M. S., *Supt.*, Marietta
Mahoning Co. Experiment Farm, Canfield
Trumbull Co. Experiment Farm, Cortland
J. PAUL MARKLEY, *Supt.*, Canfield
Belmont Co. Experiment Farm, St. Clairsville
C. W. MONTGOMERY, *Acting Supt.*,
Wooster

STATE FORESTS

Waterloo State Forest, New Marshfield
Dean State Forest, Steece

¹In cooperation with the College of Agriculture, Ohio State University, Columbus.
²In cooperation with the U. S. Department of Agriculture.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 226

FEBRUARY, 1911

THE WHEAT JOINT WORM*

By J. S. HOUSER

The wheat joint worm is a periodical visitor, but there is no regularity as to the length of time between outbreaks, nor in the number of seasons these outbreaks last. For the last half dozen years the pest has been present in destructive numbers in some sections of Ohio, occasionally the infestation being so severe that the wheat was not considered worth harvesting.

Following, as the present outbreak did, in the wake of a destructive attack by Hessian fly, the pest was at first quite generally mistaken for this insect, and indeed, not a few even yet refer to the fallen straws in the wheat fields as the work of the fly. The two insects are not the same. Aside from the marked difference in appearance of the adults, the mode of attack is no wise similar. The Hessian fly feeds upon the surface of the stalk just above the joint, sheltered by the leaf sheath, while the joint worm is found in little cells or swellings in the walls of the wheat straw. Further details of the work and habits of the Hessian fly may be found in Bulletin 177 of this Station.

WHAT THE JOINT WORM IS AND HOW THE LARVA GETS INTO THE WHEAT STRAW

While many recognize the work of the insect, few know what it really is or how it gets into the straw. The worm itself is the immature form of a tiny black insect somewhat resembling in form a winged ant. The adult female flies to the wheat fields at the time the heads are shooting and with a little, bristle-like apparatus, punctures the wheat joint, depositing in the incision a tiny egg. The egg hatches in a few days and the resulting larva begins feeding on the tissues of the wheat stalk; as a result knots or galls form, leaving the insects neatly encased. A more detailed account of the joint worm in its several stages of development will be found later under the heading of Life History.

*There are several species of joint worms injurious to grains and grasses. The species occurring in greatest numbers in Ohio in wheat is *Isosoma tritici* Fitch, corresponding with the description given by Dr. Howard in Bul. 2, Tech. Ser., Bur. Ent., U. S. D. A.

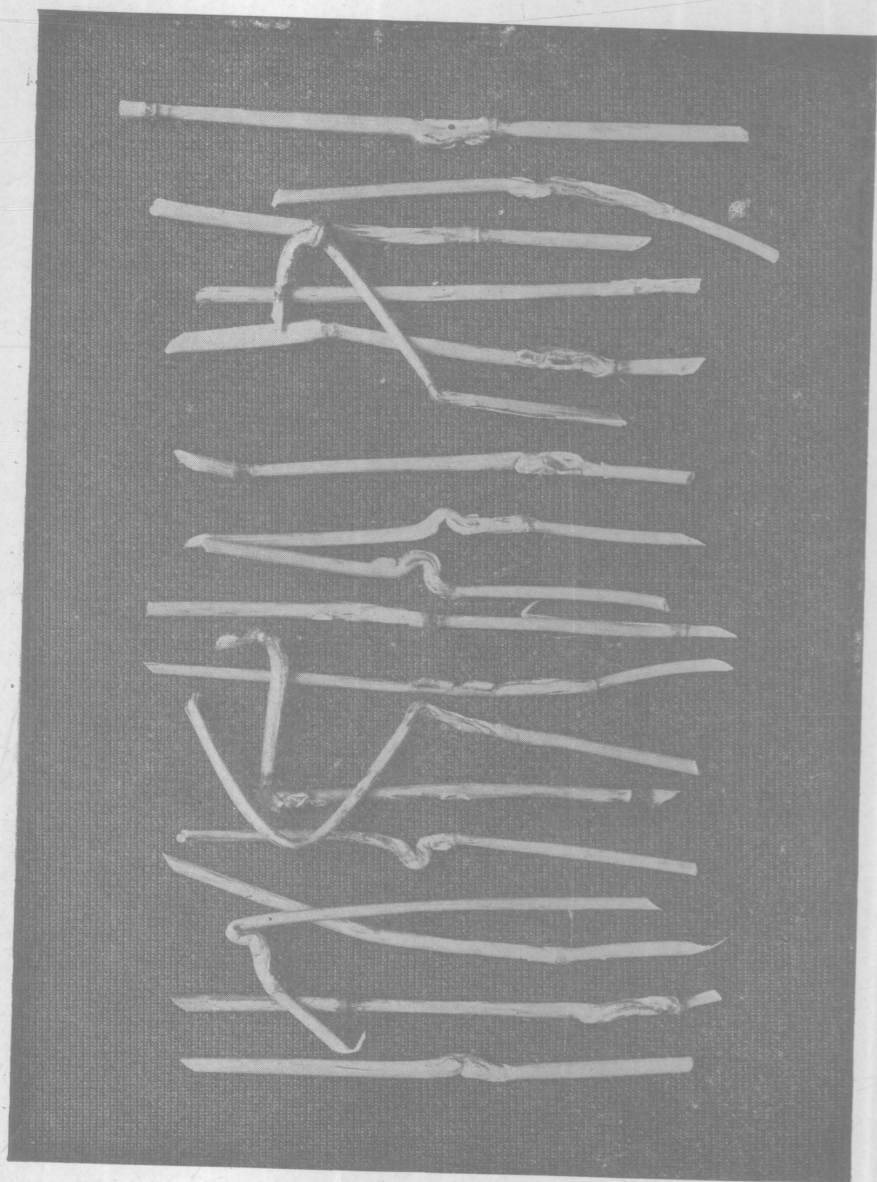


Fig. 1. Wheat straws injured by joint worm

HOW THE WHEAT IS INJURED AND THE EXTENT OF THE DAMAGE

Figure 1 shows the variable forms joint worm injury may assume. In some cases the straw is more or less distorted and the injury is plainly evident from the outside, but in others, the only external indication of injury is a slight waviness in the lines or ridges of the straw wall. In the latter case, however, if the straw is split, the gall or cell will be found to extend inward, almost completely closing the hollow area. In any event, and especially where there are several larvae near a single joint, the straw is much hardened by harvest time. These hardened straws break up in small bits when the wheat passes through the threshing machine, and being quite solid and heavy, the separator fails to clear them from the grain. The poorly cleaned wheat is frequently instrumental in bringing the joint worm to the notice of the farmer for the first time. Grain buyers and millers object to the trashy wheat, hence this is one of the ways in which the wheat joint worm does harm.

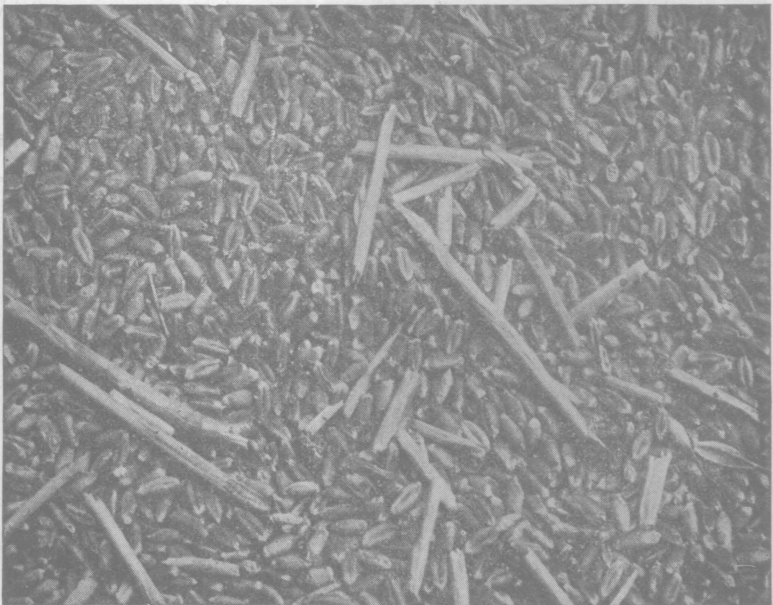


Fig. 2. Hard, woody bits of straw in the threshed grain are one of the minor results of joint worm attack

The notable absence of broken straw in the grain of the past season, even from fields badly infested with joint worm, is accounted for by the fact that the infestation was uncommonly low down on the straws. Rarely does it occur that the operations of the insect are confined so universally to the lower joints. This is probably accounted for by the fact that the season was very late and the joint worm adults came on before the upper joints were well developed.

Another way in which the joint worm does injury is by causing a certain percent of the wheat stalks to fall. As a matter of fact, however, the insect does not do the damage along this line that is generally attributed to it. When the larvae begin their work in the straw, the stalk at the point of attack at first becomes extremely flexible, and if a strong wind comes just at this inopportune time, badly infested fields are sometimes laid flat. Just such a condition existed in 1910 in the vicinity of Washington C. H., but as is usually the case, the grain straightened up again and most fields were in good condition for cutting by harvest time.

The author has rarely seen at harvest more than ten per cent of the wheat fallen on account of joint worm attack, even in fields badly infested. If the wheat stands until it begins to ripen there is less danger of infested straws breaking over than if they were free from the insect, as they are stronger rather than weaker at the point of injury.

Although the question of varieties will be taken up more in detail later, it may be well to say in passing that some varieties, being stiffer of straw than others, are less liable to fall. The accompanying illustrations, Figures 3 and 4, show two sorts grown at the Carpenter Test-farm during 1910.

Possibly the most serious result of joint worm attack is the constricting effect on the straw, which partially cuts off the food supply from the developing head of grain. However, it is difficult to determine with exactness the extent to which this occurs, because the adults seem to select straws in a certain stage of development for their egg-laying operations. Sometimes the weaker straws only, and sometimes the moderately strong ones will fall victims; hence, one can readily see that with the adults selecting a certain class of straws, the grain threshed from a given number of infested stalks, and that threshed from a similar number not infested, would not indicate perfectly the damage done by the insect.



Fig. 3. Prosperity, 67.5 percent infested. A stiff strawed sort



Fig. 4. Velvet Chaff, 85 percent infested. Note the amount fallen

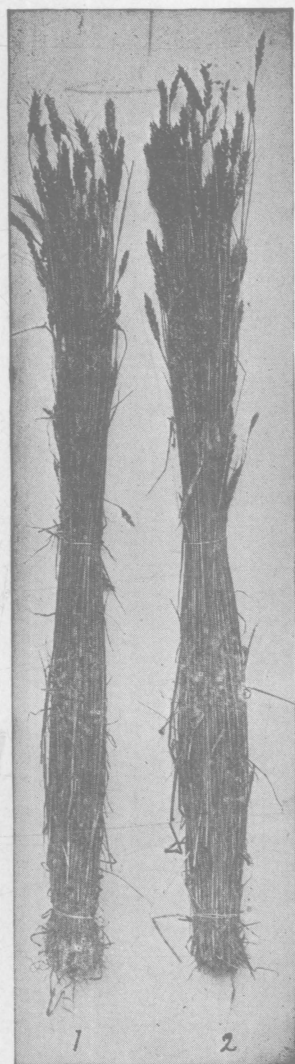


Fig. 5. A sample of wheat in which that not infested with joint worm (No. 1) is separated from that infested (No. 2). This illustrates that sometimes the mother joint worm prefers the larger straws in which to deposit her eggs.

The point is very well brought out in the following experiment: A large sample of wheat was taken this past harvest from a field near Wilmington. The wheat was average and had received the usual treatment as to seeding, fertilizing, etc. From the sample 687 infested straws and the same number, not infested were taken and the grain threshed from them. The infested straws yielded 223 grams of wheat and those not infested gave 152 grams.

It would actually seem from a cursory examination of the foregoing data that the presence of the joint worm had a stimulating effect on the plant, while as a matter of fact, the true reason for the infested bundle out-yielding the one not infested is that there was a large number of very small straws in the infested lot, which were evidently rejected as unsuitable by the egg-laying females.

HISTORY

The joint worm was first reported as a serious menace to wheat during the years 1848 to 1854 from the fields about Charlottesville and Gordonville, Va. Since that time it has been reported from most of the wheat growing districts of the United States and Canada; sometimes doing serious damage for a period of years and again almost, if not quite, disappearing for a time. Ohio, Indiana, Michigan, West Virginia, and to a lesser degree the states surrounding have suffered more severely than any others, and Ohio being in the very midst of this area has sustained her part of the loss. So far as the author is able to determine, it is not known definitely when the joint worm first reached Ohio. Certain it is, however, that the present attack, beginning in 1904, is more severe and of longer duration than any previous attack.

LIFE HISTORY

As with all other pests it is first necessary to obtain a knowledge of the life history of the joint worm before combative measures can be effectively planned and executed, and at the same time from the standpoint of the farmer there is much greater satisfaction in carrying out a plan, every phase of which he understands, than there is in following instructions blindly. The life history of the joint worm is comparatively simple, the more important phases of which, with the exception of the egg stage, can be observed quite easily, without even the aid of a magnifier.

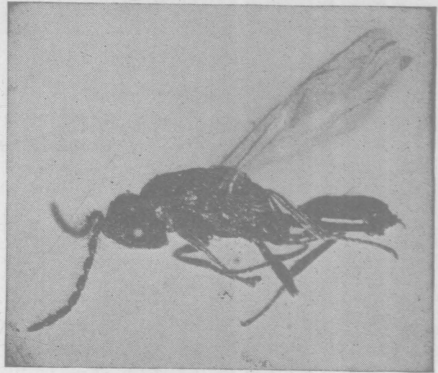


Fig. 6. The adult male joint worm insect enlarged seventeen diameters

THE ADULT

The adult male is about nine hundredths of an inch long and the female about fourteen hundredths. They have two pairs of wings and are black, with the exception of the joints of the legs and two spots on the shoulders, which are yellow. A further distinguishing mark is that the female is provided with a hair-like appendage, almost as long as the rear section of the body or abdomen, the mission of which is to pierce holes in the straw wall into which the eggs are laid. It joins the body at the base of the abdomen and when not in use rests in a groove on the under side of the abdominal segments.

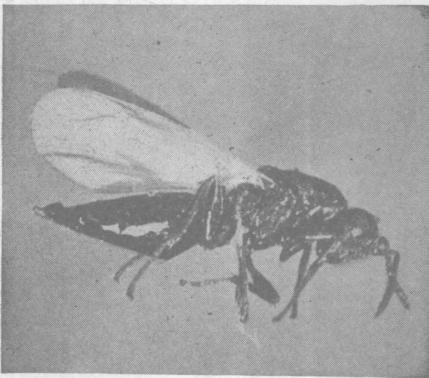


Fig. 7. The adult female joint worm insect, enlarged twelve diameters

The adult, as stated previously, emerges in the spring about the time the wheat heads are shooting. Prof. Webster* has found that parthenogenesis exists, or in other words that the females, without the intervention of the

*Cir. 66 Revised Edition, Bureau of Entomology, U. S. Department of Agriculture.

males, sometimes deposit eggs which hatch and develop mature insects. This he apparently considers unusual. The writer has observed copulation many times. Of a lot containing 382 adults

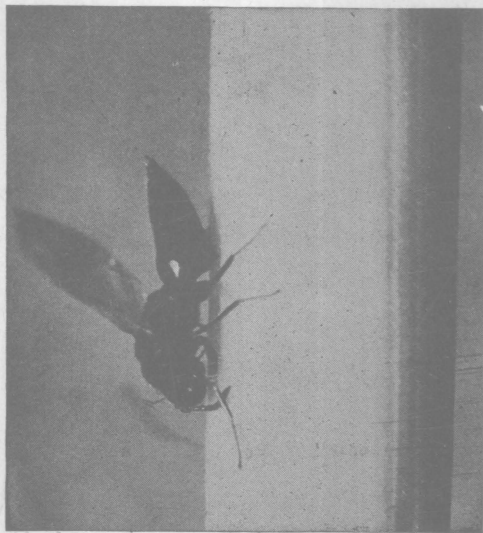


Fig. 8. The female joint worm insect with her ovipositor thrust through the leaf sheath and the straw wall into the joint. Enlarged about nine diameters

stubble gave seventy percent males of the 215 individuals captured. Thus we are led to suppose that the males remained in the stubble to copulate as the females emerged.

OVIPOSITING

The process of egg-laying was observed many times in the field as well as upon plants in the insectary and in all instances the covering leaf-sheath was pierced and the egg was deposited in one of the joints. The accompanying illustration shows a cross section of the wheat straw at the joint and the hair-like ovipositor inserted therein. The female insect alights upon the straw and walks about patting it with her antennae. She seems to be able to recognize the location of the joint with no trouble whatever, even though it is at that time

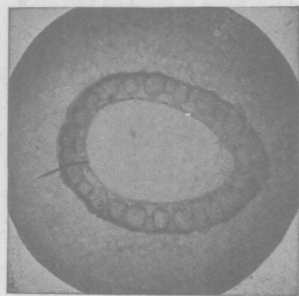


Fig. 9. A thin cross section cut through the joint of the wheat straw showing the amputated hair like ovipositor of the insect inserted therein. Enlarged about eight diameters

covered with the leafsheath. When the joint is located she places her body parallel with the straw, usually head downward, and begins drilling a hole with her ovipositor. The time required for making the incision and laying the egg varies considerably, it sometimes being accomplished in thirty seconds and at others requiring considerably over a minute.

Instinct seems to tell the mother joint worm what is the best kind of straw in which to lay her egg and in which of the joints the egg should be deposited. The state of development and strength of the straw at the time the adults appear, seems to determine in which joint the egg is to be deposited, or, indeed, whether the plant will be discarded altogether as unsuitable for the reception of the egg. Early sown, well fertilized wheat, which is not retarded by dry weather or other adverse conditions from making an early spring growth, is usually affected in the upper joints. If the reverse of these conditions prevail, however, the lower joints are more liable to be injured.

In cases of extremely severe attacks the eggs may be deposited in several joints. The season for 1909 found the joints high up in the straw attacked, while, for 1910, the lower ones were selected. It seems that by instinct the youngest joints are selected, so as to allow the longest possible time for the development of the larva before the hardening of the straw.

The younger straws are undoubtedly easier to pierce, but that the adult is fully able to pierce the harder ones was made evident by one female having thrust her ovipositor into a thoroughly dry straw in one of our insectary cages.

Although the author has no definite data to present on the subject, it would seem that the higher up the stalk is injured, the less is the resulting damage that may be expected. Without doubt the knot retards the passage of nourishment from the roots to the stalk above, and if the plant is forced to support almost the entire straw above the knot, as is the case where the lower joints are injured, as well as attempt the maturing of the head, it is believed that the chances for good grain are materially lessened. It also seems that the chances for lodging would be increased.

As a usual thing a straw of medium size is preferred to a very large one for egg laying, and at least during some seasons the extremely slender straws are rarely selected. In short, it seems that medium sized straws in which the joints are newly formed are the preferred sort for egg laying.

THE LARVA

The larva in its younger stage is almost impossible to find on account of its close color resemblance to the tissue of the green

wheat stalk. By the time the stalks are beginning to ripen, however, the protecting cells in which the larva is found are completely formed and have become quite hard and woody. At that time one

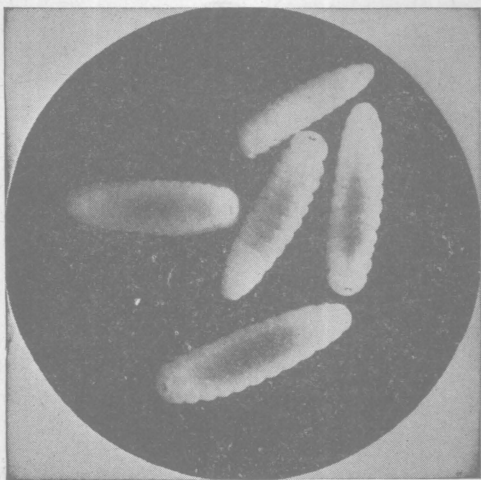


Fig. 10. Larvae of the wheat joint worm enlarged about six diameters

can break the straw crosswise through the knotty area, and there will be found, protruding from the broken end, the bodies of one or more larvae. The color is slightly yellowish and the length is in the neighborhood of sixteen hundredths of an inch. Sometimes the larvae will occur singly, while at other times as many as twenty-five will be found above a single joint, each in a single cell.

Hibernation occurs in the closed larval cells, the insect being in either the larval or pupal stage. The fact that the winter is passed in the straw walls affords us, as will be shown later, an excellent opportunity for remedial measures.

THE PUPA

The pupa is almost as large as the larva. At first it is white; then the encased antennae turn black, and after a time the whole pupal body takes on the same color. The transformation from the pupal to the adult stage occurs while the insect is still securely encased in the pupal cell.

Soon after the adult insect casts off its pupal skin it begins gnawing its way out of the pupal cell; cutting with its short, strong jaws a neat round hole through the straw wall. Those wishing to



Fig 11. A wheat straw broken open showing the protruding bodies of the wheat joint worm

obtain a sight of the adult insect may best do so by placing some of the infested straws in a glass jar during the winter months. Emergence is hastened if the jar is kept in a warm place.

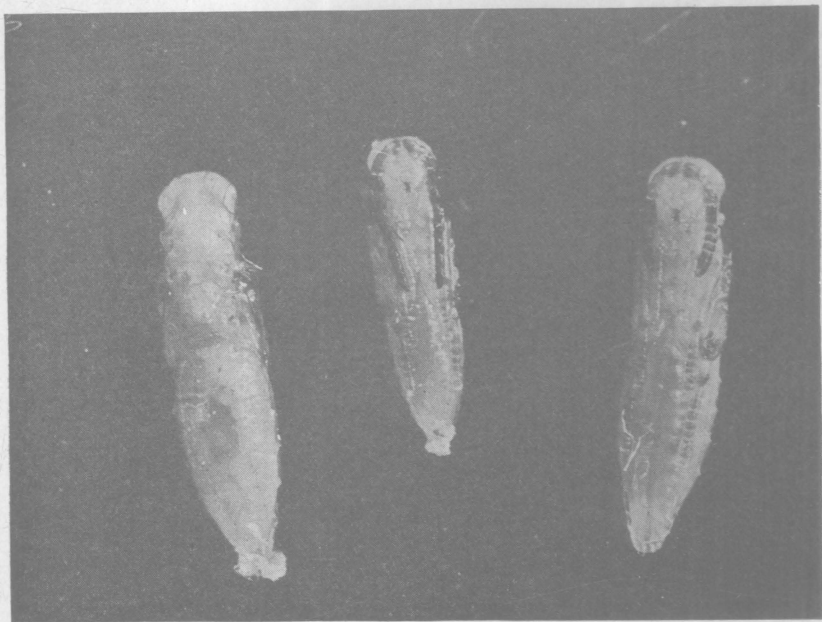


Fig. 12. Pupae of the wheat joint worm, enlarged about twelve diameters.
The central figure is that of a male.

EFFECT OF MOISTURE ON THE EMERGENCE OF ADULTS

The amount of moisture in the straw which contains the hibernating insects has much to do, in at least two important ways, with the future of the pest. If the straw is very dry preceeding and at the time of emergence of the adults it seems to weaken them and many do not escape from their cells, while on the other hand, if the straw is kept quite moist, attacking fungous diseases develop more readily. In order to determine the effect of moisture on the behavior of the pest the following experiment was arranged:

Three large glass jars were filled with stubble containing great numbers of the hibernating joint worm pupae, and were placed in the insectary November 6. Jars 1 and 2 were provided with false bottoms so that the stubble was supported above the true bottom. A little water was placed in both and an air-tight lid was clamped on No. 1, while No. 2 was covered with one thickness of cheesecloth. Jar 3 had no water in it, and after the stubble was dried out an

air-tight lid was clamped on the jar. Thus it will be seen that the atmosphere in Jar 1 was thoroughly laden with moisture, while with Jar 2 there was only a moderate amount, and in Jar 3 there was very little moisture.

Adults began to emerge from all the jars simultaneously December 17. However, very few came from Jar No. 3, while quantities came from both No. 1 and No. 2. The same phenomenon was noticed with the straw of jar No. 3 that had been noticed previously in straw kept in a dry place indoors; namely, that in many cases the straw wall seemed to be so hard that the adult insect was unable to gnaw the entire distance through it when the season for emergence came. Sometimes it would succeed in gnawing away all but a space not thicker than tissue paper, so thin in fact that the dark head of the insect could be detected, and sometimes a hole would be cut and death would occur from exhaustion or possibly from attack of mites while the insect was liberating its body. Since then the author has found, while examining straw from the interior of straw piles, that in many cases fifty percent, or more, of the adults had failed to emerge from their cells, though their bodies seemed perfectly formed and were not parasitized.

About the only bearing of economic importance which the foregoing observation has, is to indicate that the danger from straw piles as a factor in perpetuating joint worm may be overdrawn.

EFFECT OF COLD ON ADULTS

During the field observations the writer noticed that the adults did not move about freely on cold, cloudy days, remaining sluggish sometimes for a period of several days in succession when such weather conditions prevailed. With this exhibition of sensitiveness to cold, it occurred to the writer that under exceptionally cool weather conditions at the time of the appearance of the adults, they might perish. In order to obtain data on the subject some adults were forced to emerge early by confining stubble in a warm room. December 22 two test tubes containing a number of adults were exposed to out-of-door conditions, the first remaining out four minutes at a temperature of 30° Fah., and the second one remaining exposed for nineteen hours, during which time the temperature dropped to (10°). In both instances the insects stiffened out with the cold, but within fifteen minutes after they were taken indoors all revived with the exception of two from tube No. 1, that had been subjected to the least exposure. Thus it seems that cold periods during the time of emergence of the brood are not fatal to the insects. They are possibly of benefit to the wheat grower, inasmuch as they decrease the number of days of the insect's activity in the

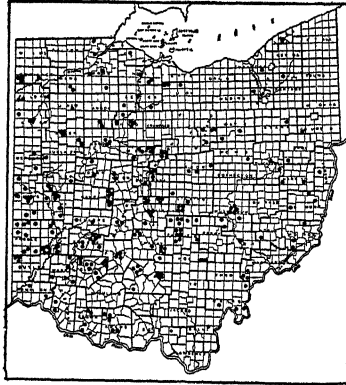


Fig. 13. Each dot marks the locality from which a report of joint worm attack was received during the year 1908. 247 reports were received.

In 1908, two circular letters of inquiry were mailed to persons located in various sections, and from these much was learned concerning the location of the more severely infested areas. In 1909 a third circular letter was sent out. In addition to the circular letters many letters of inquiry were received at the Station, during the years 1908 and 1909 and



Fig. 15. 57 reports.

egg-laying period, and for that reason the ultimate number of eggs deposited might be lessened. On the other hand, it is possible that the life of the female is somewhat prolonged if she has not had a favorable opportunity to lay her eggs.

PREVALENCE IN OHIO DURING 1908, 1909 AND 1910

The observations upon which the original part of this bulletin are based were made during the three seasons just passed. The first year's work was conducted by Messrs H. A. Gosard and W. H. Goodwin. Mr. Herbert T. Osborn assisted the writer in the second year's work, and Mr. R. D. Whitmarsh in the third.



Fig. 14. 1909, 234 reports

many fields were visited, so that in all there were obtained in 1908, 247 reports of joint worm attack, and in 1909, 234 reports were secured. In 1910 no circular letter was mailed, and there was a very noticeable falling off in the number of letters of inquiry; the latter probably being due to two causes: first, that the people have become acquainted with the joint worm, and second, that the attack was less severe than that of the two preceding years.

Figures 13, 14 and 15 indicate the locations in which it was definitely ascertained that the joint worm occurred during the years 1908, 1909 and 1910 respectively. The maps must not be understood to mean, however, that the dots show the only localities in which the insect occurred.

The study of the maps would be misleading unless carefully compared with Figure 16, which shows the wheat growing districts of the state for 1909. The production of wheat, of course, varies from year to year, but the centers remain largely the same, hence the map may be used in connection with all of the three preceding ones. The joint worm maps indicate, that of the great wheat growing sections of the state, southwestern and western Ohio suffered the most severely, and that the pest was to be encountered, at least sparingly, in most of the wheat areas.

That section of the state including Huron, Richland, Lorain, Medina, Ashland, Wayne, Summit, Portage, Stark and Holmes counties, though one of the best wheat centers, has not suffered so severely as some other parts.

More reports of extreme injury were received in 1908 than during the two later years, and it seems that the crest of the attack has passed. It is to be hoped that this is true.

VARIETIES AFFECTED

In all of our inspection trips a careful lookout has been kept for possible differences as to varieties affected. It was soon discovered that no basis for comparison could be had from examining fields here and there, on account of great variation in time of seeding, fertilizing, etc., so the variety plots at Germantown and Carpenter were used. At each place a number of varieties are grown side by side in tenth-acre plots, all receiving the same treatment as to time of seeding, fertilizing, preparation of soil, etc.

Abutting on the end of each plot was the stubble of the year previous, so that the source of supply of joint worm adults was the same for each plot.

It will be observed from a study of the following table that the differences between the varieties for 1909 are scarcely sufficient to warrant the selection of a single sort which we might call better than another. All were very badly infested. For 1910, however, the differences are more apparent; two varieties, and possibly a third, stand out with sufficient prominence to seem worthy of note: American Bronze was found to be thirty and seven-tenths percent infested; Prosperity fifty-six and two-tenths percent

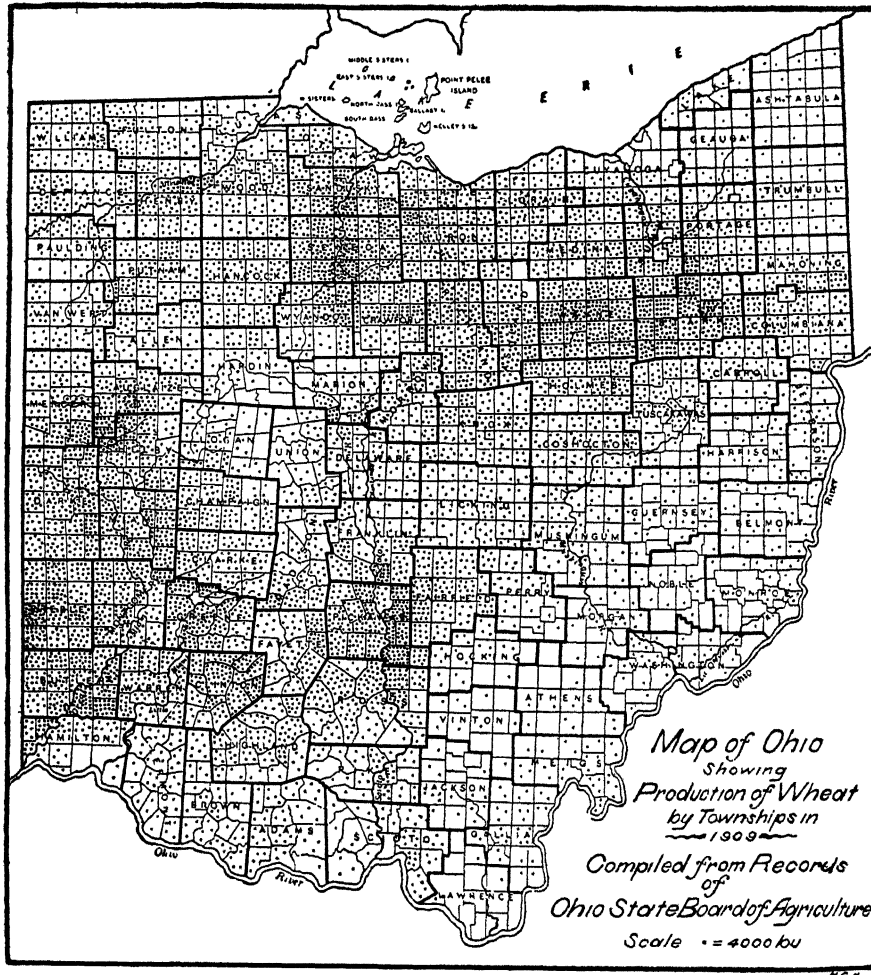


Fig. 16. From Circular 100, Ohio Experiment Station

infested, and Poole sixty-two percent infested. It is well to observe also that the yields of these varieties are above the average. Prosperity and American Bronze are both stiff strawed sorts and the plots of these varieties at the Germantown station attracted the attention of all who visited the field, as there was almost a total absence of fallen straw; while neighboring plots had a considerable amount of lodged wheat. Velvet Chaff, though rather badly infested makes a very good showing on account of its yield, which is a little above the average of the other varieties.

TABLE I. THE RESULTS OF EXAMINING VARIETIES OF WHEAT FOR DIFFERENCE IN JOINT WORM INFESTATION.

Variety	Germantown				Carpenter	
	Percent infested 1909	Yield 1909	Percent infested 1910	Yield 1910	Percent infested 1910	Yield 1910
Velvet Chaff....	93	16.46	91.6	16 2-3	85.2	21.50
Mealy.....	89	15.04	93.2	19 1-4	...	...
Fultzo-Mediterranean....	93	12.87	80.4	21 5-6	95.2	17.00
Velvet Chaff.....	95	14.50	75.6	26 1-6	...	...
Fultz.....	90	12.00	...	...	88.0	21.62
Prosperity.....	94	18.67	56.2	23	67.5	16.54
Velvet Chaff.....	84	16.00	72.0	26	...	...
Dawson's Golden Chaff....	92	16.67	72.5	24 2-3	...	...
Golden Coin.....	92	13.17	92.9	23 1-2	...	...
Velvet Chaff.....	90	13.83	73.3	22 2-3	85.0	19.21
Poole.....	94	12.12	...	...	62.0	21.37
Early Ripe.....	84	9.42	...	...	85.0	21.50
Velvet Chaff.....	97	12.57	57.7	27	...	...
Valley.....	92	10.87	73.3	25	86.4	18.21
Rudy.....	92	13.33	71.1	24 1-2	...	...
Velvet Chaff.....	91	12.58	78.8	22 1-2	...	...
Gypsy.....	95	18.79	...	...	78.8	18.71
Nigger	85	15.42	76.8	22 1-3	93.7	15.50
Velvet Chaff.....	83	12.50	80.8	23 2-3	86.8	20.17
American Bronze.....	..	...	50.7	24	...	...
Fulcaster.....	..	...	78.4	21 3-4	...	...
Red Wonder.....	..	...	17	...	...	...
Mediterranean.....	..	...	69.7	20 1-2	76.8	18.33
Turkish Red.....	..	...	89.6	20 5-6	...	...

Taken as a whole, the study of varieties, as pertains to the joint worm problem, indicates that one should select a wheat with a fair sized, stiff straw, which is known to do well in his section. The stiffness prevents falling; and if the straw is fair sized, it is believed that the presence of the joint worm larvae within its walls does not injure it to the extent that it would if the straw were undersized.

EFFECT OF FERTILIZERS

Wherever the opportunity afforded we have made it a point to examine critically fields of wheat in which a part was fertilized and a part was unfertilized. In all instances the unfertilized wheat was considerably later, both in starting off in the spring and in maturing its grain, than was the fertilized wheat.

Three opportunities were found for making the comparison; the first being the series of fertilizer plots at the Germantown station, and the second and third were afforded at Washington C. H. and Wilmington respectively. At the two latter places, fields were discovered in which the fertilizer attachment for the drill had failed to work for a couple of drill rows. For the sake of convenience these three observations will be called the Germantown Test, Washington C. H. Test and Wilmington Test.

GERMANTOWN TEST

The following table gives the plan of fertilizing the plots and the next table gives the yield per acre in this test, together with the results of our examinations:

TABLE II. PLAN OF FERTILIZING IN CORN-WHEAT-CLOVER ROTATION AT THE GERMANTOWN TEST-FARM*

Plot No.	Fertilizing materials—pounds per acre								Fertilizing elements—pounds per acre		
	On corn			On wheat				Total fertilizers for one rotation	Phosphorus	Potassium	Nitrogen
	Acid phosphate	Muriate of potash	Nitrate of soda	Acid phosphate	Muriate of potash	Dried blood	Nitrate of soda				
1	....	..	...	....	..	..	....	....	15	....	....
2	120	..	....	120	..	..	....	240	15	....	....
3	120	20	....	120	20	..	..	280	15	16½	....
4	....	..	....	....	..	..	....	....	..	....	....
5	....	20	80	....	20	30	60	210	..	16½	25½
6	120	..	80	120	..	30	60	410	15	....	25½
7	....	..	....	....	..	..	....	....	..	....	....
8	120	20	80	120	20	30	60	450	15	16½	25½
9	120	20	160	120	20	30	140	610	15	16½	50½
10	....	..	....	....	..	..	....	....	..	....	....
11	120	40	160	120	40	30	140	650	15	33	25½
12	240	20	80	240	20	30	60	710	30	16½	25½
13	....	..	....	....	..	..	....	....	..	....	....
14	240	40	160	240	40	30	140	890	30	33	50½
15	480	80	320	Lime, 1,000 pounds	....	....	....	890	30	33	50½
16	....	..	....	....	..	..	....	....	..	....	....
17	Untreated shed manure 5 tons on corn; lime 1,000 lbs. on wheat.										
18	Untreated shed manure 10 tons, 1904-5-6; lime 1,000 lbs., 1907-8-9; manure and lime on corn only.										
19	....									
20	Untreated shed manure 10 tons, 1903-4-5; lime 1,000 lbs, 1906-7-8; manure and lime on wheat only.										
21	Lime, 1,000 lbs. on corn; untreated shed manure, 5 tons on wheat.										
22	Unfertilized.										
23	Untreated yard manure, 5 tons, on corn only.										
24	Untreated shed manure, 5 tons, on corn only.										
25	Unfertilized.										
26	Phosphated yard manure, 5 tons, on corn only.										
27	Phosphated shed manure, 5 tons, on corn only.										
28	Unfertilized.										
29	Phosphated shed manure, 5 tons, on corn; lime 1,000 lbs. on wheat.										
30	Tankage, 680 lbs; muriate of potash, 80 lbs; nitrate of soda, 80 lbs. on corn; lime, 1,000 lbs. on wheat.										
31	Unfertilized.										
32	Tankage, 340 lbs; muriate of potash, 40 lbs; nitrate of soda, 40 lbs. on corn; same on wheat.										
33	Tankage, 340 lbs; muriate of potash, 60 lbs; nitrate of soda, 120 lbs. on corn; same on wheat.										
34	Unfertilized.										
35	Tankage, 220 lbs; acid phosphate, 200 lbs; muriate of potash, 20 lbs. on corn; same on wheat.										
36	Tankage, 220 lbs; acid phosphate, 200 lbs; muriate of potash, 40 lbs; nitrate of soda, 80 lbs. on corn; same on wheat.										
37	Unfertilized.										
38	Tankage, 500 lbs; muriate of potash, 60 lbs; nitrate of soda, 60 lbs. on corn; same on wheat.										
39	Tankage, 170 lbs; nitrate of soda, 18 lbs. on corn; same on wheat.										
40	Unfertilized.										

* From Bulletin 206, Ohio Agr. Exp. Station

TABLE III. YIELD PER ACRE AND PERCENTAGE OF INFESTATION

Plot	1909		1910	
	Percent infested	Bushels per acre	Percent infested	Bushels per acre
1	86	3.75	77.4	10.04
2	93	5.21	79.5	18.25
3	99	7.67	85	21.92
4	97	4.50	....	....
5	97	5.00	....	....
6	88.8	7.67	89.4	19.00
7	89.3	4.75	74.0	8.17
8	99	9.71	69.7	25.17
9	91	7.29	....	....
10	96	4.33	....	....
11	93	6.88	73.0	27.92
12	90	7.71	....	....
13	89	2.71	....	....
14	92	11.21	28.0	31.67
15	86	6.17	54.0	22.83
16	94	4.17	66.5	10.33
17	90.5	5.21	....	....
18	85	5.54	....	....
19	78	4.21	....	....
20	81	5.71	61.5	25.83
21	98	8.33	54.4	22.17
22	89	3.46	66.8	11.67
23	92	4.04	....	....
24	95	6.29	....	....
25	90	3.00	....	....
26	83	4.25	....	....
27	90	3.88	....	....
28	89	3.58	....	....
29	76	4.67	....	....
30	85	7.54	....	....
31	96	3.75	60.6	12.50
32	97	11.37	58.4	30.25
33	93	10.42	....	....
34	about 90	5.71	63.0	20.87
35	96	10.71	47.0	39.08
36	97	14.88	32.0	43.83
37	93	4.33	79.0	20.17
38	96	13.96	57.4	33.54
39	94	5.92	63.8	18.79
40	90	5.25	....	....

The following summary is of interest:

Summary of percentages	1909	1910
Average percent infested of unfertilized plots.....	90.5	69.6
Average percent infested of all fertilized plots.....	91.5	58.5
Average percent infested of all fertilized plots yielding 10 or more bus. per acre..	95.0	58.5
Average percent infested of all fertilized plots yielding less than 5 bus. per acre..	85.0	....

THE WASHINGTON C. H. TEST

Wheat sown October 1, 1908; samples taken one hundred and twenty-five yards from stubble or straw of year previous:

Unfertilized wheat 89.6 percent infested
 Fertilized wheat 35.2 percent infested

THE WILMINGTON TEST

Wheat sown last of September, 1909. Samples taken a quarter of a mile from stubble or straw of year previous:

Unfertilized wheat 15.7 percent infested
 Fertilized wheat 32.2 percent infested

A study of the data of the three tests just described reveals no evidence with respect to whether or not fertilized or unfertilized wheat is more susceptible to joint worm attack under all conditions and during various seasons. Sometimes the one and sometimes the other is more heavily infested. We can conclude, however, when we compare the yields of the plots in the Germantown test, that it pays to fertilize liberally, as the increased yield much more than offsets the harm produced by the greater percentage of infestation which prevailed in this particular case. Although we were unable to make a threshing test at Washington C. H. or Wilmington, there was no doubt that the yield of the fertilized wheat was far greater than from the unfertilized areas. If, on the other hand, fertilized wheat is sometimes more nearly exempt from infestation by joint worm, as some of our observations indicate, then this is an additional reason why fertilizers should be used.

Aside from any bearing on the susceptibility to joint worm attack which they exert on the wheat plant, fertilizers undoubtedly are of great value in assisting the plant to mature good grain in case infestation takes place. The following experiment is illustrative of this point:

Large bundles of wheat were taken from parallel plots, in which all conditions were similar except that one was fertilized and the other had received no fertilizer. The principal differences, between the two plots at harvest time which would appeal to a casual observer were, that the fertilized wheat was a little more forward, was much thicker on the ground and had in it a large number of very small straws, most of which were free from joint worm injury. These very small straws were almost wholly lacking in the unfertilized wheat, indicating, as suggested by Director Thorne, that there had been less stooling in this plot.

The infested and uninfested straws were separated in the two bundles and the wheat threshed from an equal number (687) straws from each lot. The following table gives the weight of each bundle before threshing and the amount of grain it yielded. See Fig. 5.

TABLE IV.

	Unfertilized		Fertilized	
	Infested	Not infested	Infested	Not infested
	Grams	Grams	Grams	Grams
Weight of each bundle of 687 straws before threshing..	889	636	855	657
Weight of grain from each bundle.....	210	149	223	152

It will be observed that the infested bundle from the unfertilized plot, though considerably heavier than a similar bundle from the fertilized plot, yielded less wheat than did the latter; indicating, as previously stated, that fertilizing assists in overcoming the ill effects of joint worm attack.

Taken as a whole, in the light of the data which we now possess, the relationship of fertilizers to the joint worm problem simply resolves itself into one of good farm practice; viz., that the soil should be given those elements which it most needs to produce good, vigorous wheat. If the joint worm does not come, all good and well, whereas if there is an attack, the wheat will have a far better chance of withstanding it.

TIME OF SEEDING

The date of seeding, because of its influence on the date of maturity, probably has something to do with the escape or infection of the wheat from joint worm. As has already been stated, the adult female insects seem to prefer a plant in a certain definite stage of development for their egg laying, and if one is able to sow the wheat at such a time that it would be unsuitable for oviposition when the adults appear, it is at once evident that this would be the proper procedure. Sometimes early sown wheat has been found to be more severely infested, and sometimes the late sown was found more susceptible to attack. Further complicating the problem, is the fact that some of our observations indicate that there is considerable variation in the time of emergence of the brood of adults.

Future observations may throw some light on the point, but at the present, the only dependable recommendation we can make is that the wheat be sown on that date which with average conditions has been found to yield the best crop. The joint worm may or may not attack it. If it does, the plants, on account of their vigor, will be better able to withstand the injury.

DANGER OF INFESTATION FROM STRAW STACKS

On account of the known fact that the joint worm passes the winter in the walls of the wheat straw, from which it emerges the following spring ready to injure the new crop, much emphasis has been placed in years past upon the danger of letting straw stacks stand from one season until the next. It is the opinion of the writer that the danger from this source has been given undue prominence, because it is his belief that a smaller percentage of adult insects emerge from the straw than we have supposed.

As shown previously in the paragraph dealing with the effect of moisture on the emergence of the adults, many of the insects perish when the straw is kept very dry, and it is well known that this

condition exists in a well made straw stack. Examinations of straw from the interior of straw stacks have shown, many times, that a large percentage of the insects were dead from some cause other than parasitic attack. Again, Prof. Webster* has shown that large numbers of the insects perish in the straw stacks through the activities of a tiny mite, *Pediculoides ventricosus* Newport.

It is not suggested, however, that the disposal of waste straw should be completely ignored, for the condition of the surface of the stack is such that undoubtedly many adults overwinter therein to emerge the following spring. It is manifest that poorly stacked straw, or badly scattered straw, should receive attention. The point the author wishes to bring out is that if a farmer has a well built stack of dry straw, it seems unnecessary to burn it for no other reason than its liability to breed joint worm adults.

DANGER OF INFESTATION FROM STUBBLE

Just as the danger from straw stacks has been unduly emphasized, it is the opinion of the writer that the great danger from the old stubble has been too little considered. It is believed that old stubble, standing from one season to the next, does more towards inviting joint worm attack than does any other practice or combination of practices. Fortunately, the remedy in this case is more effective and easier of execution than any other measure to be employed against the pest. And in this connection it may be noted that that side of a field which adjoins stubble of the year previous has been found more heavily infested with joint worm than any other portion. The following observations bear upon the point under consideration: During the season of 1909, a field of wheat about two hundred and fifty yards wide was found near Washington C. H., one side of which adjoined a field of badly infested stubble. It was a considerable distance to stubble on the three remaining sides. A large sample of the wheat was taken from the side of the field adjoining the stubble, a second from the middle and a third from the opposite side. These samples were then examined for joint worm with the following results:

1. Wheat adjoining stubble 95.0 percent infested
2. Wheat from middle of field 125 yds. from stubble... 35.0 percent infested
3. Wheat from far side of field 250 yds. from stubble.. 24.5 percent infested

A similar observation was made at Germantown (1910) on the tenth-acre plots. One end of each plot adjoined stubble of the year previous and the opposite end was ninety-one yards distant. The same plan of sample taking was followed as with the preceding:

*Circular 118 Bureau of Entomology U. S. Department of Agriculture.

1. End of plot adjoining stubble 82.5 percent infested
2. Middle of plot 53.7 percent infested
3. End of plot opposite stubble 52.5 percent infested

These observations not only indicated that wheat adjoining stubble is more severely infested than that grown some distance away, but in addition, throw some light upon the power of flight of the mother insect of the joint worm. While making the observations of 1909, the inquiry arose as to how far the adults would fly before ovipositing, and a diligent lookout has been kept since that time for a field of growing wheat a long distance from any stubble or straw of the year previous. During the past season a hundred-acre field was found near Wilmington, the center of which was more than a quarter of a mile from any stubble or straw, and between the field and the nearest stubble extended a strip of woods which was two hundred or more yards wide. The wheat near the center of the field was found to be 32.2 percent infested.

It therefore can be stated definitely that the joint worm adults will fly at least a quarter of a mile, and it is probable that under stress they will fly much farther.

NATURAL ENEMIES

The joint worm is beset by at least four classes of enemies, which, named in the order of their importance, are as follows:

1. Parasitic insects.
2. Predaceous mites.
3. Fungus diseases.
4. Insect eating animals.

PARASITIC INSECTS

Several species of parasites have been bred from our joint worm material; the one which by all odds occurs in greatest numbers being *Ditropinotus aureoviridis* Cwfd. The female of this little



The yellow parasite, *Ditropinotus aureoviridis* Cwfd., enlarged about eleven diameters.

parasite has a yellowish color and is about two-thirds as large as the joint worm adult. It is fitted with an ovipositor much the same as its host, with which it punctures the straw wall, and deposits an egg upon the body of the joint worm larva within. As the joint worm is expert in detecting the joint of the wheat straw, so the parasite is equally proficient in discovering the

cells of the joint worm larvae. These minute insects may be seen just prior to harvest diligently searching about over the wheat straws, or with their bodies flattened against the straw wall and their ovipositors thrust down deep into the interior of the cell of a joint worm. The eggs laid at this time quickly hatch into larvae which begin feeding on the body of the host. They complete their development before fall and emerging as adults, again search out the cells of undestroyed joint worm larvae and deposit eggs. These eggs hatch and the resulting larvae pass the winter in the straw, emerging as adults at the following harvest.

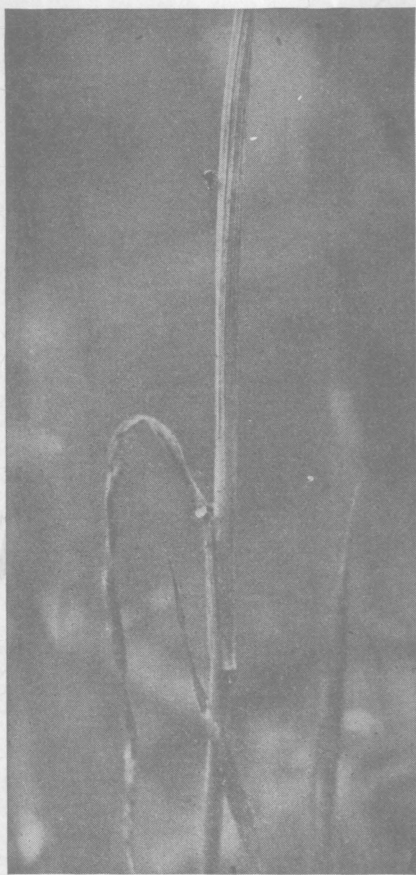


Fig. 18. The yellow parasite laying her egg upon the body of an encased joint worm larva. Photo taken in the field

PREDACEOUS MITES

It has been found, as reported in Circular 118, Bureau of Entomology, U. S. Department of Agriculture, that a tiny, eight-legged mite, *Pediculoides ventricosus* Newport, is very active in destroying the joint worm, especially after the straw is stacked or placed in the mow. According to the author of this Circular the mites make their way into the joint worm cells through the puncture of some parasitic insect, or when the joint worm fly attempts to eat its way through the straw wall, the little fellows swarm into the first small opening made by

the encased insect and kill the fly before it emerges. Unfortunately, however, the mite possesses no discriminating taste between the joint worm and the valuable parasitic insects, and the latter are therefore destroyed as well as the former. In all probability, as suggested in the Circular before named, it is due to these mites that the natural parasites have not overcome and controlled the present attack of joint worm long before this time.

In addition to its undesirable practice of destroying our friends, the parasites of the joint worm, this mite makes itself further obnoxious by swarming upon the bodies of the laborers when they are working about straw in which it is abundant. The more tender portions of the body are more severely affected, and, on such parts as the back, chest, abdomen and back of the arms, tiny welts or swellings form which itch distressingly. Sometimes these welts are so abundant that they form a solid mass. For want of a better name the mites causing this condition are generally alluded to as "chiggers." The trouble is frequently brought into the house in straw mattresses where it attacks those occupying the beds. In mows, it sometimes causes stock stabled below to become almost frantic; and in potteries, packing houses, etc., the workmen frequently refuse absolutely to have anything more to do with the infested straw. Where it is essential that straw so infested be used, fumigation with carbon bisulfide or hydrocyanic acid gas will kill the mites, but if this is not convenient or practicable the following recommendations are made:

Before working in the straw, dust a quantity of flowers of sulfur in the clothing and as soon as possible after the day's work, change clothing and bathe in strong soapsuds. If the mites have already commenced work on the body apply an oily, cooling lotion to the affected parts. Where the infested straw is to be stored in mows, first apply a heavy sprinkling of sulfur to the floor.

FUNGIOUS DISEASES

During the two seasons just passed the author has found great quantities of the over-wintering pupae which had been destroyed by a fungous disease. This disease has been determined by Mr. T. F. Manns of this Station as *Sporotricum globuliferum*, the well known chinch bug disease. It may be well to say in passing that in recent years the spreading of the disease artificially is considered of questionable value.

INSECTIVOROUS ANIMALS

The revised edition of Circular 66, Bureau of Entomology, U. S. Department of Agriculture, reports the finding of wheat straws from which the joint worm larvae had been deftly eaten out by some small animal. This is not very common in Ohio, as the author has observed but two instances where this had occurred: once, during the spring, in stubble land and again during the summer in growing wheat which bordered on woods. In the latter place about three to five percent of the straws had been cleared of the joint worm larvae.

REMEDIES

The burning of the stubble of the year previous is by all odds the easiest and most effective measure to be used against the wheat joint worm. It is rarely possible to burn in the fall on account of the injury that would result to the young clover, but unless the season is very exceptional, there is always a time during the winter or spring after the clover has been frozen down when the stubble may be burned quite easily. Those who have burned in the spring have found that the clover suffered no appreciable damage. If the stubble is thin, harrowing it down will facilitate burning, and if very thin it may be necessary to harrow it down and rake it up into piles. If the stubble is burned before the clover starts in the spring, this will be early enough to destroy all of the hibernating joint worm insects.

The burning of the stubble on a single farm would be of some value, but in order for the measure to be largely effective, the stubble upon all the surrounding farms should be burned also, as it has already been shown that the joint worm insects travel long distances in search of growing wheat.

There would be some loss in soil fertility by the burning of the stubble, but for a few years, while the scourge of joint worm prevails, it is thought that the better farm practice will be to burn, regardless of the loss in fertility which it causes. Badly scattered or useless straw also should be burned.

The other remedies to be employed are nothing more than a thorough system of progressive farm practice. By all means, sow a variety which is known to do well locally, and it is quite desirable that the variety should be a stiff, large strawed sort. Fertilize liberally and with those elements in which the soil is deficient. If it is not known what the soil needs write to the Experiment Station, and the Department of Soil Fertility will be glad to render all the service possible.

Concerning the proper date for sowing, it has been suggested by Prof. H. A. Gossard, in Press Bulletin 317 of this Station, that it is unwise to depart from the normal date. By normal date is meant that date upon which wheat sown through a large series of years is found to give the best average returns. The dates indicated on the accompanying map for the various sections of the state are suggested by Prof. C. G. Williams of this Station as approximately normal.

ACKNOWLEDGMENTS

In addition to those, as previously noted, who have been connected with the work attending the preparation of this Bulletin, the writer wishes to thank especially Prof. H. A. Gossard for suggestions and criticisms and Prof. C. R. Crosby of Cornell University for criticisms of the manuscript. Figures 1, 5 and 7 are by Mr. Beeching, photographer of the Station and Figure 12 is by Mr. Goodwin.



Normal dates for sowing wheat in Ohio